CHAPTER VI

CONCLUSION AND RECOMMENDATION

Since many conventional waterflood cases are unable to achieve the highest oil recovery as the reservoirs can fully provide, water alternating gas injection (WAG) process is one of the enhanced oil recovery method that can be used to obtain an incremental oil recovery. The WAG process is performed by injecting water and gas alternately. A combination of effect of water and gas injection is gained in the WAG process. Gas injection helps reduce residual oil saturation but can lead to viscous fingering. Water injection provides a better sweep efficiency but leaves more residual oil. Therefore, water and gas injection can complement on each other when combined in the WAG process.

This thesis aims at the optimization of WAG process. Two reservoir models were constructed in this study. The first model is black oil reservoir model. And, the other is compositional model. Important parameters to be optimized are water-gas ratio and cycle size. The effects of horizontal permeability, vertical to horizontal permeability ratio, and locations of the producer and injector were investigated in both models. Moreover, due to the fact that hysteresis effect is generally involved during the WAG process, an investigation was performed on such effect using two different models: (1) Killough model and (2) Larsen and Skauge model. Killough model is the main model used throughout the optimization in both black oil and compositional models due to its availability in the simulator we used whereas the effect of Larsen and Skauge model was investigated only in the black oil model. The results of the study can be concluded as follows:

1. The WAG process, when appropriately implemented, proves to achieve higher recovery factor than waterflood in both black oil and compositional models because, gas slugs leave less oil saturation whereas waterflood leaves more oil in the reservoir.
2. The WAG process simulated by the compositional model yields higher recovery factor than the one simulated by the black oil model. In the compositional model, reduction in residual oil results in higher recovery factor. It can be pointed out that the compositional simulator can model the

WAG process better than black oil simulator since the compositional model can handle the composition exchange between components of reservoir fluid and injected gas.

3. The optimum water-gas ratio for the compositional model is 0.25 whereas the optimum value for the black oil model is 1. It can be said for the compositional model that the higher the amount of injected gas, the higher the recovery factor.
4. The most appropriate cycle size is the same in black oil and compositional models, i.e., the smaller the cycle size, the higher the recovery factor. This is because water and gas slugs cannot effectively complement one another when the slug size is large.
5. Horizontal permeability does not have an effect on the most appropriate water-gas ratio and cycle size of WAG process in both reservoir models. However, the value of recovery efficiency does change with varying value of horizontal permeability.
6. Effect of vertical to horizontal permeability ratio on individual WAG case can be seen more apparently in the compositional model than in the black oil model. But vertical to horizontal permeability ratio does not affect the most appropriate water-gas ratio and cycle size.
7. In both reservoir models, impact of locations of the producer and injector can only be seen when the cycle size is large. For cases with large cycle size (24 and 36 months), if the two wells are not too far from each other, more recovery factor can be obtained by increasing the volume of injected water. However, the most appropriate water-gas ratio and cycle size does not change with this parameter.
8. Killough relaltive permeability hysteresis model can implement the hysteresis effect on non-wetting phase (gas) only. In the compositional model, the gas relative permeability curve shows different behaviors of the scanning curve. Larsen and Skauge relative permeability hysteresis model can implement the hysteresis effect on both non-wetting and wetting phases.

Recommendation

From the conclusion of the results in this study, it is worth to point out that further study of optimization of WAG process may include the investigation of reservoir heterogeneity since an actual reservoir always contains heterogeneity. If the Larsen and Skauge relative permeability hysteresis model is used, it should be used with great care.